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Title: Contraction in Action

Subject Area(s): Advanced Biology/Anatomy and Physiology

Grade(s): 10-12

Description of Lesson: The contraction of a sarcomere involves the integrated effort of motor neurons, neurotransmitters, active transport, calcium ions, ATP, and several proteins, that work with great speed. This activity is designed to help the students visualize not only the structure of a sarcomere, but the actual physical action, and the rapidity, of its contraction and relaxation. It is intended as a follow-up to a discussion of the material. The activity, in turn, may be followed up by a student-built three dimensional model.

Students are placed into groups of 6 to 8, and they must divide themselves into separate roles and cooperatively design a skit that shows both the anatomical and physiological nature of a sarcomere contracting and relaxing, as well as the neural stimulation that preceded it. Emphasis is given to the visual, rather than merely the verbal, imparting of information. Ideal performances include equality of roles, drama, the use of props, music (!), and, of course, scientific accuracy.

Should one not actually plan on emphasizing muscle contraction in one's curriculum, this activity is a good way of integrating the concepts of active transport, facilitated diffusion, exocytosis, oxygen and energy usage, etc., into a coherent whole. This is an excellent summative activity for the information is applied in a real life situation.

Length of Lesson: One hour for lecture and 0.5-1 hour for the construction/presentation of the skits

Student Objectives: Students will be able to work collaboratively to construct a 2-4 minute skit on the topic of muscle contraction.

Materials:
Various resources for demonstrating muscle contraction
Video recording device
Access to YouTube

Procedure:
Once the actual structure and function of the sarcomere has been taught, one can actually begin this activity.

Give the students is a list of roles that are needed, with the understanding that the size of the group necessitates some students playing more than one role. These roles include, but are not necessarily limited to: ACh, AChE, ACh receptor, Na^+ ions, SR, Ca^{2+} ions, Myosin and Myosin heads, Actin and Myosin-binding sites, Troponin, Tropomyosin, ATP, Mitochondria. Given the need for the students to come into physical contact, one must put certain rules into place as to what parts of the body are O.K. (e.g. holding hands, feet touching) and what parts are off limits.

The students will be put in groups of 6 to 8, and they are given 20 to 30 minutes to write, design, direct, and block out (determine location and movement) a skit that illustrates the function of a sarcomere, and all the steps involved in its contraction and relaxation.

Each student must have a speaking part, with no one person dominating the performance.

The performance must be scientifically accurate, and be a predominantly VISUAL representation of a sarcomere.

Students are limited to whatever is in the room at the time for their props (coats, books, pens, paper, scissors, tape, etc.).

At the end of the period the groups will perform their skits in front of the class and would be recorded.

The recordings would then be uploaded onto YouTube for analysis.

The homework for the week would then be for the students to find at least three different errors in the presentations in regards to scientific accuracy and to post their comments onto the YouTube discussion board.

Scientific Explanation:

Depending upon the level of the class, one may opt to concentrate less on the role of the nerves and the role of active transport in the contraction of muscle tissue. For a complete lesson, one must provide the following information to the student in one form or another:

1. Muscle contractions are instigated by nerve impulses.
2. The place where motor neurons and muscles meet is called the neuromuscular junction (NMJ). Instead of the two touching, there is a space called a synapse across which the message travels.
3. At the axon terminal (the end of the motor neuron) there are vesicles filled with a neurotransmitter, for example: Acetylcholine (ACh). When the nerve impulse is sent, the vesicle fuses with the cell membrane and releases the ACh by exocytosis.
4. Active transport, in the form of the Na^+/K^+ pump, is used by the myofibers (muscle cells) to maintain a higher concentration of Na^+ outside the cell membrane.
5. On the sarcolemma (muscle cell membrane) there are ACh receptors (30 to 40 million at a typical NMJ!) that will open up a channel when ACh attaches, allowing the Na^+ to flood into the cell through facilitated diffusion.
6. Inside the myofibers are sarcoplasmic reticula or SR (a muscle cell's version of the endoplasmic reticulum or ER) that store Ca^{2+} ions by active transport. The change in Na^+ concentration due to the ACh causes the SR to release Ca^{2+} in the same flood-like fashion.
7. The contraction of the sarcomere involves the binding of the proteins Actin (thin filament) and Myosin (thick filament). Given that these will bind automatically due to their shapes, there must be a way to prevent contraction when necessary. Contraction is prevented by the protein molecules Troponin and

Tropomyosin, which wrap around the Actin molecules, covering the Myosin-binding site on the Actin molecule.

8. The Ca^{2+} ions which were released earlier bind to the Troponin molecules, thus causing them to change shape, and in turn cause the Tropomyosin to change shape, thus exposing the Myosin-binding sites. The Ca^{2+} ion binding to the Troponin acts as a key to the gas cap (padlock), thus opening up access to the tank (locker).

9. Heads on the Myosin molecule, appropriately called Myosin heads, then bind with the Actin. This is called a cross bridge and causes the rigidity of the muscles. The binding also changes the shape of the molecules thus moving the thin filament closer to the center of the sarcomere.

10. When ATP is present it is needed to break the bond between the Actin and the Myosin filaments. The Myosin heads contain the enzyme ATPase, which breaks ATP down into ADP and a phosphate, and releases energy. Due to the change in shape, this break forms a power-stroke that moves the thin filament closer to the center and allows the Myosin-binding site to bind to the next Myosin head.

11. The repeated breaking and forming of bonds is the contraction of the sarcomere, and it necessitates a great deal of ATP.

12. Relaxation is, in essence, a reversal of much of contraction. Given that the ACh starts the whole process, its removal from the synapse is one of the first steps of relaxation. Acetylcholinesterase (AChE) in the synaptic cleft breaks down the ACh, thus closing the ACh receptors and allowing the high concentration of Na^{+} ions to be reestablished by active transport and remain on the outside of the sarcolemma.

13. Active transport pumps in the SR then work toward keeping the concentration of Ca^{2+} ions 10,000 times higher in the SR than in the sarcoplasm (myofiber cytoplasm). This uptake of Ca^{2+} ions is facilitated by the binding of Ca^{2+} ions to a protein called calsequestrin in the SR.

14. The lack of Ca^{2+} ions in the sarcomere causes the Troponin and Tropomyosin to block the Myosin-binding sites on the Actin, thus preventing the cross bridges from forming.

15. It is important for the students to know that relaxation alone will not return a muscle to its previous length, but that it requires the contraction of an antagonistic muscle (i.e. biceps and triceps).

Assessment:

Since each of the groups will perform in front of the class, I would not only give a group grade, but I would also have the students "vote" to grade the other groups by "secret ballot." I would then average the students' grade votes for each group. This grade will become 25% of the groups' final grade. If a supportive and honest atmosphere exists, the students tend to grade each other quite fairly and honestly. Part of my grade will also include an assessment of their cooperation as a group during the planning stages and their participation within the analysis of the YouTube videos.

Some of the criteria I would use are:

- scientific accuracy
- visualization over verbalization
- brevity of narrative (supportive only)
- teamwork and equality of planning and roles
- creativity and enthusiasm

Missouri and Kansas Standards Addressed:

Kansas Science Standards:
Standard 3, Benchmark 5: Benchmark 5: The student will develop an understanding of matter, energy, and organization in living systems

Missouri Science Standards:
Strand 3.2, Concept C. Complex multicellular organisms have systems that interact to carry out life processes through physical and chemical means

*This lesson has been modified from Michael Lazaroff's post at:
http://accessexcellence.com/AE/AEC/AEF/1996/lazaroff_contraction.php